J. D. Jackson: Elements of Style

Drawn from his books, summer school lectures, reviews, incidental papers, and letters.

Robert N. Cahn

September 26, 2016

The Book

What the student sees:

14.16 Exploiting the fact that $k_0 d^3N/d^3k$, the number of quanta per invariant phase-space element d^3k/k_0, is a Lorentz-invariant quantity, show that the energy radiated per unit frequency interval per unit solid angle, (14.79), can be written in the invariant and coordinate-free form

$$\hbar\omega \frac{d^3N}{d^3k} = \frac{4e^2}{3\pi^2 m^2}\left[\frac{(p\cdot k)^2}{[d^2(p\cdot k)/d\tau^2]^2}\left(\frac{d(\epsilon_1\cdot p)}{d\tau}\right)^2 K_{2/3}^2(\xi) + \frac{(p\cdot k)(\epsilon_2\cdot p)^2}{2[d^2(p\cdot k)/d\tau^2]}K_{1/3}^2(\xi)\right]$$

where $d\tau$ is the proper time interval of the particle of mass m, p^μ is the 4-momentum of the particle, k^μ is the 4-wave vector of the radiation, and ϵ_1, ϵ_2 are polarization vectors parallel to the acceleration and in the direction $\epsilon_1 \times \mathbf{k}$, respectively. The parameter is

$$\xi = \frac{2\sqrt{2}}{3m}\cdot\frac{(p\cdot k)^{3/2}}{(|d^2(p\cdot k)/d\tau^2|)^{1/2}}$$

What the Book is Really About:
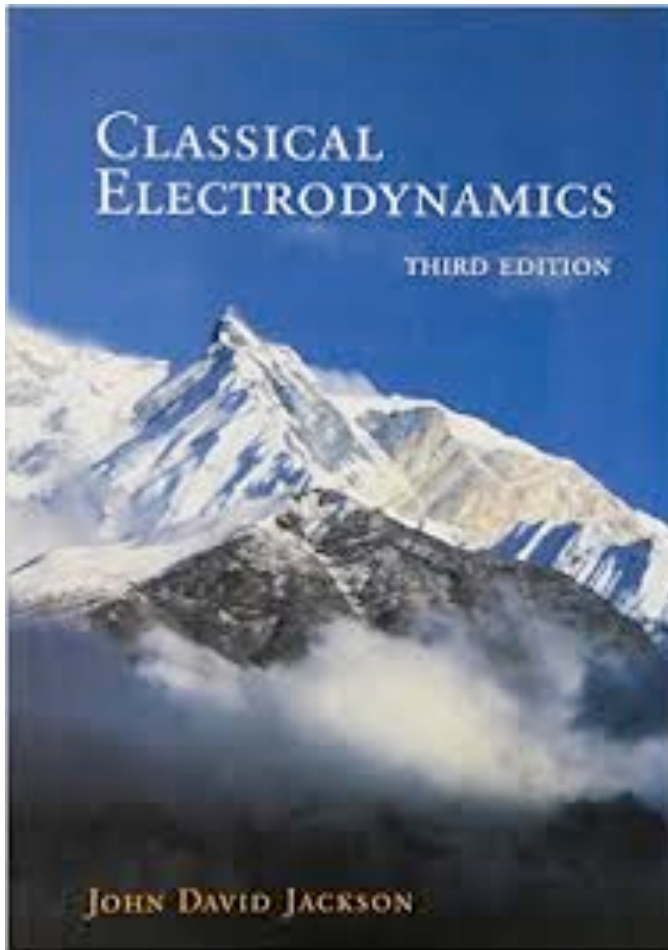
Light
Reflection
Absorption
Radiation
Water
Air
Scattering

Nature is comprehensible, but it takes real work!

- There are no short cuts to the goal.
- Choose the right path.

Jackson before "Jackson"

THE PHYSICS OF

ELEMENTARY PARTICLES

By J. D. JACKSON

PRINCETON, NEW JERSEY
PRINCETON UNIVERSITY PRESS
1958

1958

9.2. Beta Decay Interaction without Space Inversion and Time Reversal Invariance

We have seen from our general arguments in Chapter 8 that if the beta process is demanded to be invariant under space inversion and time reversal, only certain combinations of vectors can appear in the distribution functions—true scalars under space inversion and time reversal. The interaction Hamiltonian (9.1) was the most general Lorentz invariant form consistent with these requirements:

$$H_{\text{int}} = \sum_j C_j (\bar{\psi}_p \mathcal{O}_j \psi_n)(\bar{\psi}_e \mathcal{O}_j \psi_\nu) + \text{h.c.}, \qquad (9.1)$$

Table 10. Transformation of the Beta Decay Interaction Under the Operations P, C, and T expressed as changes in the Coupling Constants

Operation	Ordinary interaction	γ_5-type interaction	Requirement for invariance	
Unity	C	C'	—	—
Space Inversion	C	$-C'$	—	C' vanish
Charge Conjugation	$C*$	$-C'*$	C real	C' pure imaginary
Time Reversal	$C*$	$C'*$	C real	C' real

To illustrate the form of terms which appear when we allow the possibility of lack of invariance under P, C, T, we consider the simple case of

[120] The essential point is that γ_5 is an operator which transforms like a scalar under proper Lorentz transformations. Consequently its presence in the second term of (9.10) does not spoil the Lorentz invariance. But the space inversion operation is $P\psi(\vec{x}) = \gamma_4 \psi(-\vec{x})$. Thus $P(\gamma_5\psi(\vec{x})) = -\gamma_5 P\psi(\vec{x})$, and there is a change of sign which makes the corresponding term in (9.10) a pseudoscalar.

At Home in the Complex Plane

INTRODUCTION TO DISPERSION RELATION TECHNIQUES

J. D. JACKSON
Physics Department, University of Illinois

1
HISTORICAL SURVEY OF DISPERSION RELATION TECHNIQUES

TODAY the words " dispersion relations " or " spectral representations " cover a multitude of sins. But the basic thread running through all of the various manifestations is the idea that quantum mechanical amplitudes for physical processes are the boundary values of analytic functions of one or more complex variables. Right from the very beginning in the original work of Kramers, complex variable theory has played a role. And today the emphasis is more and more on the exploitation of the
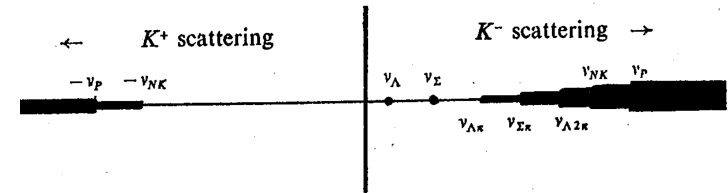
1960 Scottish Summer School

Fig. 3

for zero or small Q^2. The branch cuts start at $\nu = \nu_{\Lambda\pi}$ for $\nu > 0$. Hence there is a *large* unphysical domain, $\nu_{\Lambda\pi} < \nu < \nu_P$, where experimental information is not available. For forward scattering the various energies are $\nu_\Lambda = 0\cdot13\mu$, $\nu_\Sigma = 0\cdot31\mu$, $\nu_{\Lambda\pi} = 0\cdot49\mu$, $\nu_{\Sigma\pi} = 0\cdot69\mu$, $\nu_{\Lambda2\pi} = 0\cdot89\mu$.

The pole terms can be calculated in a straightforward way. For forward scattering they give contributions to the dispersion relations of the form,

$$B_\Lambda^- = \frac{g_\Lambda^2}{2N} \frac{1}{\nu_\Lambda - \nu} \left(\frac{\nu_\Lambda + N + \Lambda}{\nu_\Lambda + N - \Lambda} \right) \qquad \ldots\ldots\ldots(6.22)$$

and a corresponding term from the Σ pole. For K^+ scattering change the sign of ν. The upper (lower) line in (6.22) is taken if the parity of ($K\Lambda$) is the same as (different from) N. The ($K^\pm + p$) forward scattering dispersion relation now takes the form,

$$M_\pm(\nu) = B_\Lambda^\pm(\nu) + B_\Sigma^\pm(\nu) + \frac{1}{4\pi^2} \int_{\nu_{\Lambda\pi}}^{\mu} \frac{\sqrt{\mu^2 - \nu'^2}\,\sigma_{\text{abs}}^-(\nu')}{\nu' \pm \nu}\,d\nu'$$

$$+ \frac{1}{4\pi^2} \int_{\mu}^{\infty} \sqrt{\nu'^2 - \mu^2} \left[\frac{\sigma_{\text{total}}^-(\nu')}{\nu' \pm \nu - i\varepsilon} + \frac{\sigma_{\text{total}}^+(\nu')}{\nu' \mp \nu - i\varepsilon} \right] d\nu'. \qquad \ldots\ldots\ldots(6.23)$$

Summer School Circuit: Recipes for Analysis

WEAK INTERACTIONS

J. D. Jackson
University of Illinois

Brandeis 1962

$$d\omega = \frac{G^2}{16\pi^2} m_\pi^3 m_\ell m_\nu \left| f_S - \frac{m_\ell}{m_\pi} f_V \right|^2 \cdot$$

$$\cdot \left| \bar{u}_\ell (1+\gamma_5) u_\nu \right|^2 \frac{d^3p}{p_0} \frac{d^3q}{q_0} \delta^4(p+q-Q)$$

(3.5)

The two-body phase space integral,

$$\iint \frac{d^3p}{p_0} \frac{d^3q}{q_0} \delta^4(p+q-Q)$$

can be seen from Eq. (C.1) to be equal to $32\pi^2$ times Eq. (C.3); or from Eq. (D.3), to be equal to Eq. (D.15) with $\mu^2 = \rho^2 = m_\ell^2$ and $K^2 = -m_\pi^2$. Therefore the decay rate is

$$d\omega = \frac{G^2}{8\pi} m_\pi^3 m_\ell m_\nu \left(1 - \frac{m_\ell^2}{m_\pi^2}\right) \left| f_S - \frac{m_\ell}{m_\pi} f_V \right|^2 \cdot \left| \bar{u}_\ell (1+\gamma_5) u_\nu \right|^2$$

(3.6)

The sum over spins of the neutrino and lepton is easily found to be

$$\sum_{spins} \left| \bar{u}_\ell(p)(1+\gamma_5) u_\nu(q) \right|^2 = -\frac{2p \cdot q}{m_\ell m_\nu} = \frac{m_\pi^2}{m_\ell m_\nu}\left(1 - \frac{m_\ell^2}{m_\pi^2}\right)$$

Density Matrices à la Gottfried-Jackson

Particle and Polarization Angular Distributions for Two and Three Body Decays

J. D. Jackson

University of Illinois

Les Houches 1965

$$p_{\perp x}(\theta, \varphi)\, W_{\frac{3}{2}}(\theta, \varphi) = \frac{3}{4\pi}\, \eta_\alpha \eta_\beta \eta_\gamma \left\{ \left[\frac{1}{2}(\rho_{\frac{1}{2}\frac{1}{2}} - \rho_{-\frac{1}{2},-\frac{1}{2}})(3\cos^2\theta - \frac{1}{3}) \right. \right.$$
$$\left. + \frac{1}{2}(\rho_{\frac{3}{2}\frac{3}{2}} - \rho_{-\frac{3}{2},-\frac{3}{2}})\sin^2\theta \right]\sin\theta$$
$$- \frac{1}{3}\cos\theta(9\cos^2\theta - 5)\,\mathrm{Re}(\rho_{\frac{1}{2},-\frac{1}{2}}e^{i\varphi})$$
$$- \sqrt{3}\,\sin^2\theta\,\cos\theta\,\mathrm{Re}\left[(\rho_{\frac{3}{2}\frac{1}{2}} + \rho_{-\frac{1}{2},-\frac{3}{2}})e^{i\varphi}\right] +$$

$$+ \frac{1}{\sqrt{3}}\sin\theta(3\cos^2\theta - 1)\mathrm{Re}\left[(\rho_{\frac{3}{2},-\frac{1}{2}} - \rho_{\frac{1}{2},-\frac{3}{2}})e^{2i\varphi}\right]$$
$$+ \sin^2\theta\,\cos\theta\,\mathrm{Re}(\rho_{\frac{3}{2},-\frac{3}{2}}e^{3i\varphi}) \right\} \qquad (5.13)$$

$$p_{\perp y}(\theta, \varphi)\, W_{\frac{3}{2}}(\theta, \varphi) = \frac{3}{4\pi}\, \eta_o \eta_\beta \eta_\gamma \left\{ (\frac{1}{3} + \cos^2\theta)\,\mathrm{Im}(\rho_{\frac{1}{2},-\frac{1}{2}}e^{i\varphi}) \right.$$
$$+ \frac{1}{\sqrt{3}}\sin^2\theta\,\mathrm{Im}\left[(\rho_{\frac{3}{2},\frac{1}{2}} + \rho_{-\frac{1}{2},-\frac{3}{2}})e^{i\varphi}\right]$$
$$- \frac{1}{\sqrt{3}}\sin 2\theta\,\mathrm{Im}\left[(\rho_{\frac{3}{2},-\frac{1}{2}} - \rho_{\frac{1}{2},-\frac{3}{2}})e^{2i\varphi}\right]$$
$$\left. - \sin^2\theta\,\mathrm{Im}(\rho_{\frac{3}{2},-\frac{3}{2}}e^{3i\varphi}) \right\} \qquad (5.14)$$

Monumental Reviews of Hadronic Interactions

Regge Theory

Finite-Energy Sum Rules

Models for High-Energy Processes*

J. D. JACKSON

Department of Physics and Lawrence Radiation Laboratory, University of California, Berkeley, California

Glauber model

Recent developments in the concepts and models used to describe high-energy collisions of fundamental particles are reviewed. The areas of appreciable activity in research in high-energy physics are surveyed briefly and the general framework for the description of processes at high energies is outlined. There follows a sampling of recent experimental data designed to show the extent and detail of present-day experimental results. Recent applications of Regge pole models are reviewed with emphasis on the difficulties as well as the successes of models employing only Regge poles. The various multiple-scattering models are then discussed and correlated by means of the methods of Glauber. The connection of these models with amplitudes having branch cuts in the angular-momentum plane (Regge cuts) is described, as well as some comparisons with experiment. Finite energy sum rules as a means of relating the low-energy and high-energy domains are discussed in some detail. Next, the far-reaching concept of duality whereby the direct-channel resonances *are* (in some sense) the crossed-channel Regge exchanges is described, along with the related ideas of exchange degeneracy, the special role of the Pomeranchon Regge pole, and duality diagrams. An explicit realization of duality is achieved in the Veneziano model. This model is discussed in some detail for the relatively simple and interesting example of pion–pion scattering. Brief mention is also made of the extensions of the Veneziano model to the n-particle amplitude, attempts at unitarization, and various applications. The topic of multiparticle final states is covered relatively briefly with emphasis on the applications of double Regge pole exchange to three-body final states, the calculation of proton and pion energy and angular distributions in proton–proton collisions by means of the multi-Regge exchange model, and the generation of self-consistent Regge singularities with the multi-Regge exchange model and unitarity. The final section of the review concerns recent results on pion–pion scattering phase shifts and also $K-\pi$ phase shifts, and some remarks on theorems connecting decay correlations of resonances with the mechanism of production. The literature survey ended, with a few exceptions, in May 1969.

Exchange Degeneracy

Veneziano model

Duality

Love Affair with Special Functions

Framed picture hung on Jackson's office wall.

Physics 224C: Supplementary notes on Problem 2-5 (1969)

J. D. Jackson

April 28/69

Physics 224C

Supplementary notes on Problem 2-5

The amplitude involving $(-\cos\theta)^{\alpha(\ell)}$ is not permissible because of a cut in $\cos\theta$ in the physical region ie from $0 \to \infty$. We can modify the amplitude to eliminate this deficiency as follows:

$$A(\ell,\cos\theta) = -\pi\beta(\ell)\left[\frac{(-\cos\theta)^{\alpha(\ell)}}{\sin\pi\,\alpha(\ell)} + \frac{1}{\pi}\int_0^{z_0} dz\,\frac{z^{\alpha(\ell)}}{z-\cos\theta}\right]$$

The added integral is easily shown to have a discontinuity $0 \to z_0$, just opposite to the first term. Consequently the discontinuity is

$$\frac{1}{2\pi i}\ \text{disc}\ A(\ell,z) = \beta(\ell)\,z^{\alpha(\ell)}\,\theta(z-z_0).$$

If $z_0 > 1$ this is an acceptable behavior. Note that the added integral is over a finite interval. For ___ behavior is as z^{-1}. Thus, if $\alpha > 0$ the Regge behavior of the first term will dominate at large $|z|$.

Partial wave projection

1. Direct evaluation with series for $Q_\ell(z)$.

To evaluate $A(\ell,z) = \beta\int_{z_0}^\infty dz\,z^\alpha\,Q_\ell(z)$ we can use the ___ hypergeometric function in

$$Q_\ell(z) = \frac{\sqrt{\pi}\,\Gamma(\ell+1)}{2^{\ell+1}\,\Gamma(\ell+\frac{3}{2})}\,\frac{1}{z^{\ell+1}}\,F\!\left(\frac{\ell+2}{2},\frac{\ell+1}{2};\ell+\frac{3}{2};\frac{1}{z^2}\right)$$

We obtain

$$A(\ell,z) = \frac{\beta\sqrt{\pi}\,\Gamma(\ell+1)}{2^{\ell+1}\,\Gamma(\ell+\frac{3}{2})}\sum_{m=0}^\infty \frac{\left(\frac{\ell+2}{2}\right)_m \left(\frac{\ell+1}{2}\right)_m}{m!\,\left(\ell+\frac{3}{2}\right)_m}\,\frac{1}{z_0^{\ell-\alpha+2m}}\times\frac{1}{(\ell-\alpha+2m)}$$

provided $\operatorname{Re}(\ell-\alpha) > 0$. Here $(a)_m = \frac{\Gamma(a+m)}{\Gamma(a)} = a(a+1)\cdots(a+m-1)$.

The series can be shown to converge for $\operatorname{Re}(\ell-\alpha) > 0$, giving an analytic function for $A(\ell,z)$, provided $\operatorname{Re}\ell > \operatorname{Re}\alpha$. We can continue it into the region, $\operatorname{Re}\ell < \operatorname{Re}\alpha$. Evidently there are poles at $\ell_n = \alpha - 2n$, $(n=0,1,2,\dots)$. Their residues are clearly independent of z_0 and can be computed to be

$$(\text{Residue})_n = \frac{\beta\sqrt{\pi}\,\Gamma(\alpha+1)}{2^{\alpha+1}\,\Gamma(\dots)\,n!\,\Gamma(\alpha+\frac{3}{2}-m)}$$

Are these ___ correct? ___ in dealing with $z < 1$ in Problem 2-5, this is the same residue as found by using Gradshteyn-Ryzhik, formulas 7.126-4 or 7.133-1. This is probably fortuitous, however, because these formulas are incorrect for $z_0 \neq 0$. (See #3 below).

2. Use of integral representation for $Q_\ell(z)$

With $Q_\ell(z) = \frac{1}{2 z^{\ell+1}}\int_0^1 dt\,t^{\frac{\ell-1}{2}}(1-t)^{\frac{\ell}{2}}\left(1-\frac{t}{z^2}\right)^{-\frac{\ell}{2}-1}$

we can cast $A(\ell,z)$ into the form,

$$A(\ell,z) = \frac{\beta}{2}\int_0^1 dt\,t^{\frac{\ell-1}{2}}(1-t)^{\frac{\ell}{2}}\int_{z_0}^\infty dz\,z^{\alpha-\ell-1}\left(1-\frac{t}{z^2}\right)^{-\frac{\ell}{2}-1}$$

By changing variables in the z integral, ___ $(z_0/z)^2$ this ___

$$\dots = \frac{z_0^{\dots}}{2}\dots\left(1-\frac{\dots}{z_0^2}\right)^{\dots-1}$$

The integral is recognizable (with a little practice!) as a hypergeometric function. $A(\ell,z)$ can thus be written as

$$A(\ell,z) = \frac{\beta}{2}\,\frac{z_0^{\alpha-\ell}}{\ell-\alpha}\int_0^1 dt\,t^{\frac{\ell-1}{2}}(1-t)^{\frac{\ell}{2}}\,F\!\left(\frac{\ell+2}{2},\frac{\ell-\alpha}{2};\frac{\ell-\alpha}{2}+1;\frac{t}{z_0^2}\right)$$

The formula in the Bateman manuscript is actually in error.

In the Bateman Manuscript Project's "Tables of Integral Transforms", Vol. 2, p. 399, (7) there is the desired integral. The formula is actually in error. On the RHS, in the function $_3F_2$, the argument σ should be $(\rho + \sigma)$. When this is corrected, we obtain

$$A(\ell, s) = \frac{\beta}{2} \frac{z_0^{\alpha-\ell}}{(\ell-\alpha)} \frac{\Gamma\left(\frac{\ell+1}{2}\right)\Gamma\left(\frac{\ell+2}{2}\right)}{\Gamma\left(\ell+\frac{3}{2}\right)} \, _3F_2\left(\frac{\ell+2}{2}, \frac{\ell-\alpha}{2}, \frac{\ell+1}{2}; \frac{\ell-\alpha}{2}+1, \ell+\frac{3}{2}; \frac{1}{z_0^2}\right)$$

Pochhammer's generalized hypergeometric function

The function $_3F_2$ is one of Pochhammer's generalizations of the hypergeometric function. Examination of its series expansion shows that the series obtained for $A(\ell, s)$ is exactly the one on the bottom of p. 1, found so much more easily with the series expansion for $Q_\ell(z)$ in powers of z^{-1}.

3. <u>Errors in Bateman Manuscript Project volumes</u>

Errors in Bateman Manuscript Project volumes

It would appear that we could use Gradshteyn-Ryzhik 7.126-4 (equivalent to T.I.T., Vol. 2, p. 325, (26)). This gives

$$A(\ell, s) = \beta \, \Gamma(\alpha+1) \, e^{i\pi(\alpha+1)} \left(z_0^2 - 1\right)^{\frac{\alpha+1}{2}} Q_\ell^{-\alpha-1}(z_0).$$

Then G-R, p.999, defines $Q_\ell^{-\alpha-1}$ in terms of $_2F_1$. This leads to

$$A(\ell, s) = \frac{\beta\sqrt{\pi}}{2^{\ell+1}} \frac{\Gamma(\alpha+1)}{\Gamma(\ell+\frac{3}{2})} z_0^{\alpha-\ell} \Gamma(\ell-\alpha) F\left(\frac{\ell-\alpha+1}{2}, \frac{\ell-\alpha}{2}; \ell+\frac{3}{2}; \frac{1}{z_0^2}\right)$$

For arbitrary $z_0 > 1$, this amplitude has poles at $\ell = \alpha - m$. The leading pole at $\ell = \alpha$ has the same residue as found above. But the poles at $\ell = \alpha-1, \alpha-2, \dots$ have different residues (which depend on z_0). The only conclusion seems to be that the integral in the books is incorrect.

For $z_0^2 \to 0$ we can transform $F(\dots, \frac{1}{z_0^2}) \to F(\dots, z_0^2)$. This gives $A(\ell, s) = \frac{\beta\sqrt{\pi}}{2^{\alpha+2}} \frac{\Gamma(\alpha+1)(-1)^{\alpha-\ell}}{\Gamma(\frac{\ell+\alpha+3}{2})} \Gamma\left(\frac{\ell-\alpha}{2}\right)$, which has the correct

"The only conclusion seems to be that the integral in the books is incorrect."

1974 November Revolution

J D JACKSON

Spear results (Kadyk call, ~4 pm)

Peak in $e^+ e^-$ cross section at
$$W = 2(1.552)\, GeV = 3.104\, GeV$$

$$R \gtrsim 150 \qquad \sigma \sim 1500\, pb$$
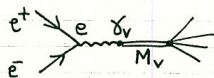
$$(FWHM)_{observed} = 2\, MeV$$

$$\frac{\Delta E}{E} \sim 3 \times 10^{-5}$$

Note that R_{max} for ρ is $\sim 6.5 - 7.0$

Presently mapping out the peak.
Yield of hadrons at peak is qualitatively
similar to yield at nearby energies.

See OVER

For $e^+ e^- \to$ state n, the resonant cross section is

$$\sigma_n = \frac{(2J+1)\pi \lambdabar^2}{(2s_1+1)(2s_2+1)} \frac{\Gamma_{e^+ e^-}\, \Gamma_n}{(M-W)^2 + \left(\frac{\Gamma}{2}\right)^2}$$

where $\Gamma = \sum_m \Gamma_m$ is the total width.

We have $2J+1 = 3$, $(2s_1+1)(2s_2+1) = 4$, $\lambdabar^2 = \frac{1}{k^2} = \frac{4}{s} = \frac{4}{W^2}$
The total cross section is therefore

$$\sigma = \frac{3\pi \times 4}{W^2 \times 4} \frac{\Gamma_{e^+ e^-}\Gamma}{(M-W)^2 + \frac{\Gamma^2}{4}}$$

$$\sigma_{max} = \frac{12\pi}{W^2}\cdot \left(\frac{\Gamma_{e^+ e^-}}{\Gamma}\right)$$

$\sigma_{\mu\mu} = \frac{4\pi \alpha^2}{3W^2}$ we have $R = 9(137)^2 \left(\frac{\Gamma_{e^+ e^-}}{\Gamma}\right)$

$$\overline{R_{max}} = 255 \qquad \therefore \frac{\alpha \overline{R_{max}}}{3} = 0.620$$

$$\overline{\left(\frac{d\sigma/d\Omega}{}\right)_{QED}} = \left| -1 + \frac{0.620}{x - \lambda}\right|^2 + 0.385\left(\frac{\Delta W}{\Gamma}\right)\left[\frac{1}{1+x^2}\right]$$

where $x = (M-W)\cdot \frac{2}{(\Gamma + \Delta W)}$.

$$= 1 - 1.24\frac{x}{1+x^2} + 0.385\left(1 + \frac{\Delta W}{\Gamma}\right)\frac{1}{1+x^2}$$

Observed peak value is $\sim 80 - 100\, mb$ whereas QED value is 9. This means

$$\frac{(\Gamma + \Delta W)}{\Gamma} \simeq \frac{(8-10)}{.385} \sim 20-25.$$

With $\Delta W = 1.3\, MeV$, $\Gamma \simeq 52. - 63.\, KeV$

If $\sigma_{\mu\mu} \sim 123\, mb$, $\frac{\Gamma + \Delta W}{\Gamma} \simeq \frac{13.6}{.385} = 35.4$

With $\Delta W = 1.3\, MeV$, $\Gamma = 37\, KeV$.

This means $R_{max} = 8.9 \times 10^3$

Now $R_{max} = 9(137)^2 \frac{\Gamma_{ee}}{\Gamma}$ $\therefore \frac{\Gamma_{ee}}{\Gamma} = \frac{8.9\times 10^3}{9(137)^2} = .053$

$\left[\frac{e^+ e^- \to e^+ e^-}{}(90°)\right]_{QED} \simeq \frac{1}{9}\left(8 + (8-12)\right) \simeq 1.8 - 2.2.$

Beautiful! $\quad \Gamma \simeq 40 - 60\, KeV$
$$\frac{\Gamma_{ee}}{\Gamma} \simeq 0.053 \simeq \frac{\Gamma_{\mu\mu}}{\Gamma}$$

Note $\Gamma_{ee} = \frac{\overline{R}}{9(137)^2}\Delta W = 2.0 \times 10^{-3}\, MeV$ for $\overline{R} = 255$, $\Delta W = 1.3\, MeV$ independent of value of Γ.

JDJ's Drawing

Became cover of CERN Courier
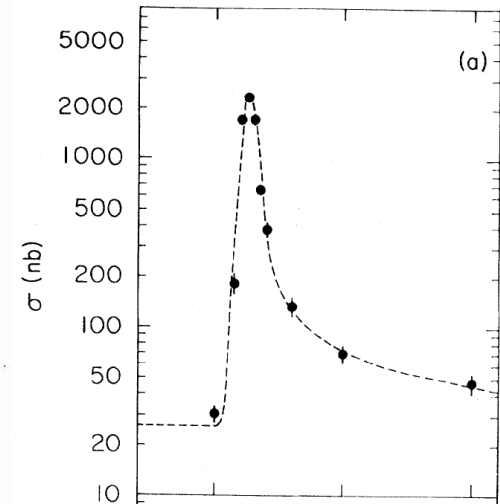
Peak in e+e- cross section at ψ resonance.

Roy Schwitters's Version

J D Jackson Commemoration
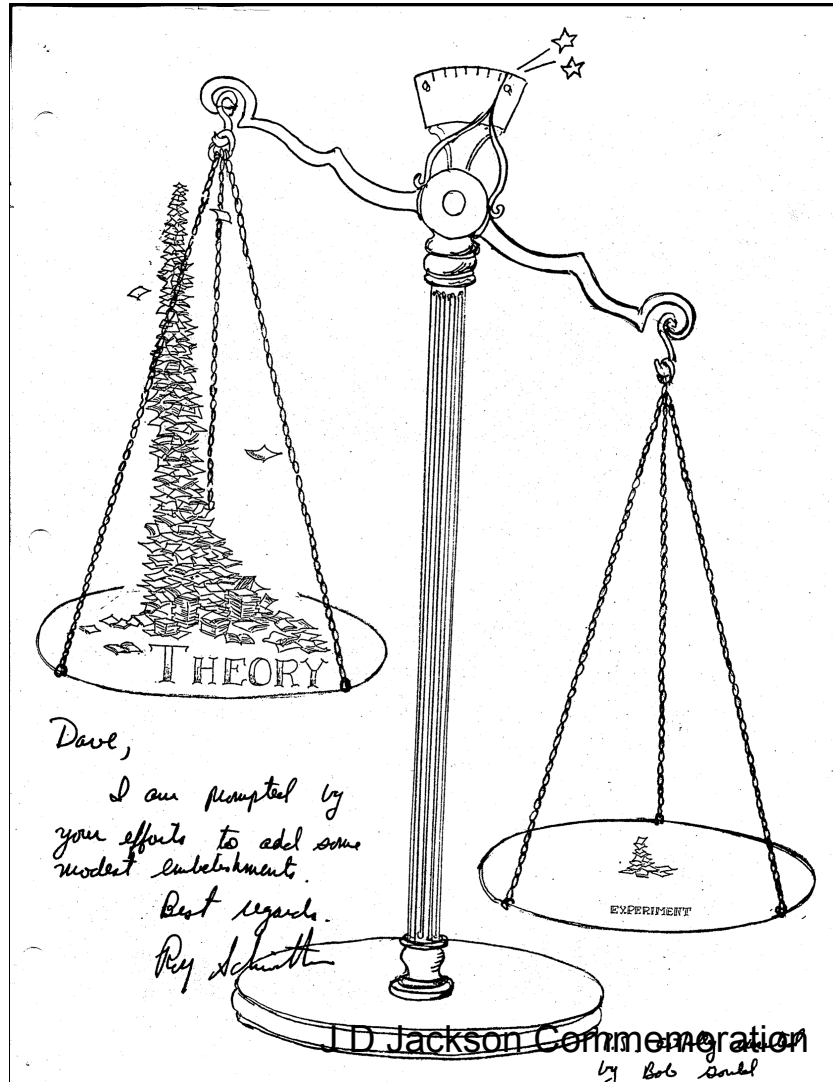
Quintessential Jacksonian Problem:
Spin-Flip Synchrotron Radiation
RMP 48, 417 (1976)

- Important for polarized e+e-.

- Didactic – follows Sokolov, Ternov,..Baier & Katkov.

- Based on work of one of his heroes, L. H. Thomas.

- Interplay of classical and quantum mechanical.

- Marvelous special functions.

- Emphasis on physical understanding.

- Intriguing result: final polarization $8/(5\sqrt{3})$=92%
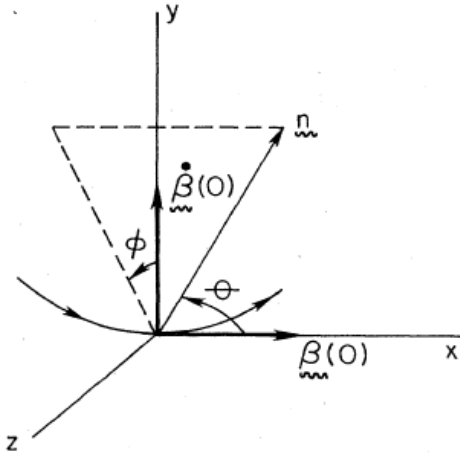
Spin-Flip Synchrotron Radiation

FIG. 3. Coordinate system used in the calculations. The orbit lies in the x–y plane with x and y axes defined by the directions of $\vec{\beta}$ and $\dot{\vec{\beta}}$ at $t = 0$. The unit vector $\vec{n}$ specifies the direction of the photon wave vector $\vec{k}$.
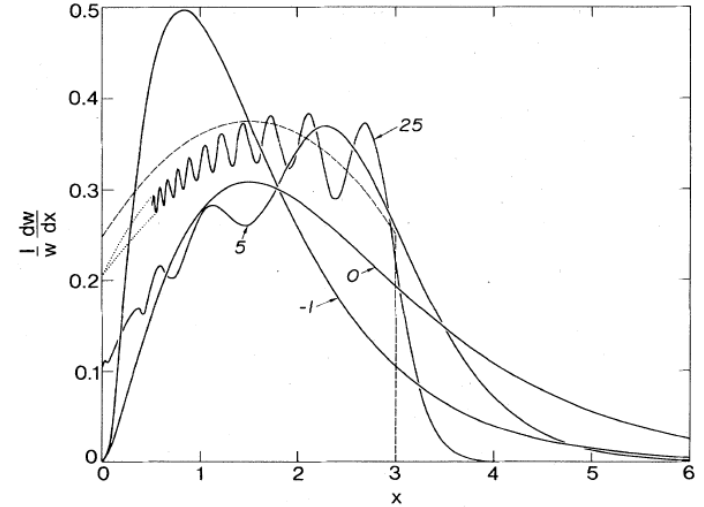

FIG. 4. Normalized frequency spectra for the number of photons per unit frequency interval of the "down" transition [Eq. (58) with $\theta_0 = 0$] for different values of the anomaly, a. The abscissa variable is a scaled frequency, $x = \nu(1 + 16a^2/81)^{-1/2}$. The numbers adjacent to the curves are the values of a. The total transition probabilities are very different for different values of a; the curves have been normalized to unit area to facilitate comparison of their shapes. The dashed curve is the asymptotic spectrum ($|a| \to \infty$) of Eq. (14).

$$\frac{d^2w}{d\Omega\,d\omega} = \frac{8(3\nu/4)^{7/3}}{5\pi\sqrt{3}\,\tau_0\gamma^2\omega_0}\left\{\sin^2\theta_0\left[(1 - at^2)^2\big|\mathrm{Ai}(z_0)\big|^2 + a^2t^2\left(\frac{4}{3\nu}\right)^{2/3}\big|\mathrm{Ai}'(z_0)\big|^2\right]\right.$$

$$+ \tfrac{1}{4}(1 - \cos\theta_0)^2\left[t^2\left|(1+a)\mathrm{Ai}(z_+) + a\left(\frac{4}{3\nu}\right)^{1/3}\mathrm{Ai}'(z_+)\right|^2 + \left|\left[1 + a\left(1 + t^2 + \frac{2a}{3\nu}\right)\right]\mathrm{Ai}(z_+) + (1+a)\left(\frac{4}{3\nu}\right)^{1/3}\mathrm{Ai}'(z_+)\right|^2\right]$$

$$+ \tfrac{1}{4}(1 + \cos\theta_0)^2\left[t^2\left|(1+a)\mathrm{Ai}(z_-) - a\left(\frac{4}{3\nu}\right)^{1/3}\mathrm{Ai}'(z_-)\right|^2 + \left|\left[1 + a\left(1 + t^2 - \frac{2a}{3\nu}\right)\right]\mathrm{Ai}(z_-) - (1+a)\left(\frac{4}{3\nu}\right)^{1/3}\mathrm{Ai}'(z_-)\right|^2\right]\right\}.$$

Nature of Intrinsic Magnetic Dipole Moments (1977)

- Current loop or separated poles?

B

$+$

$-$

$$\Delta E(\text{hyperfine}) = -|\psi(0)|^2 \mu_e \cdot \int_{r<R} \mathbf{B}(\mathbf{r}) d^3 r$$
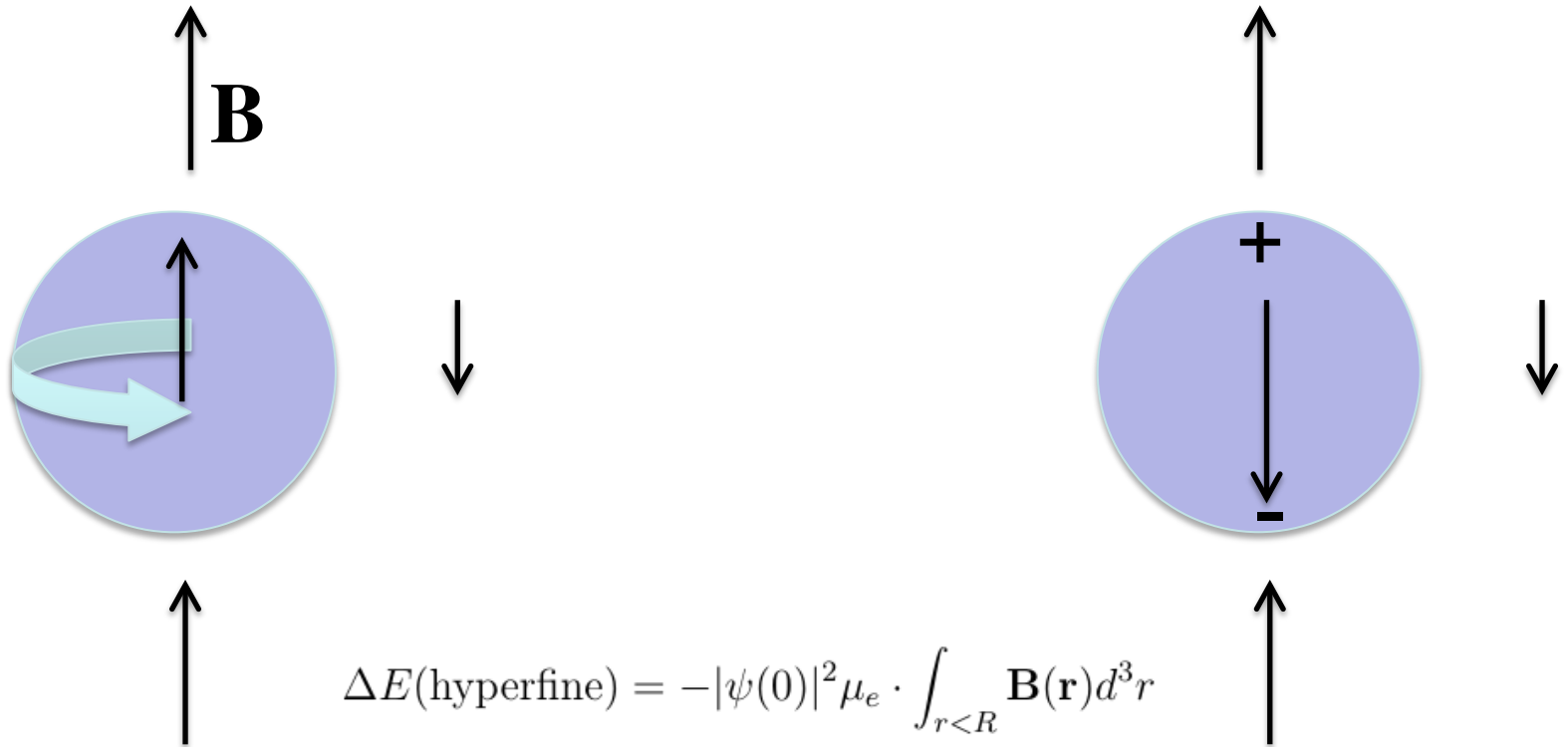
The Reader Can Easily…

Current

$$\Delta E(\text{hyperfine}) = -|\psi(0)|^2 \mu_e \cdot \int_{r<R} \mathbf{B}(\mathbf{r}) d^3r$$

$$\int_{r<R} \mathbf{B}(\mathbf{r}) d^3r = \int_{r<R} \nabla \times \mathbf{A}(\mathbf{r}) d^3r$$

$$\int_{r<R} \mathbf{B}(\mathbf{r}) d^3r = \int_{r=R} d\mathbf{S} \times \mathbf{A}(\mathbf{r})$$

$$\mathbf{A}(r) = \frac{1}{c} \int d^3r' \frac{\mathbf{J}(r')}{|r-r'|}$$

$$d\mathbf{S} = \hat{\mathbf{r}} d\Omega$$

$$\int_{r<R} \mathbf{B}(\mathbf{r}) d^3r = -\frac{R^2}{c} \int_{r'<R} d^3r' \mathbf{J}(r') \times \int_{r=R} d\Omega \frac{\hat{\mathbf{r}}}{|r-r'|}$$

$$\int_{r=R} d\Omega \frac{\hat{\mathbf{r}}}{|r-r'|} = \frac{4\pi}{3} \hat{\mathbf{r}}' \frac{r_<}{r_>^2}$$

$$\int_{r<R} \mathbf{B}(\mathbf{r}) d^3r = \frac{4\pi}{3c} \int_{r'<R} \mathbf{r}' \times J(r') d^3r'$$

$$\mathbf{m} = \frac{1}{2c} \int \mathbf{r}' \times \mathbf{J}(r') d^3r'$$

$$\int_{r<R} \mathbf{B}(\mathbf{r}) d^3r = \frac{8\pi}{3c} \mathbf{m}$$

Charge

$$\phi_M(r) = \int \frac{\rho_M(r')}{|r-r'|} d^3r'$$

$$\int_{r<R} \mathbf{B}(\mathbf{r}) d^3r = -\int \nabla \phi_M d^3r = -R^2 \int \hat{\mathbf{r}} \phi_M(r) d\Omega$$

$$\int_{r<R} \mathbf{B}(\mathbf{r}) d^3r = -R^2 \int d^3r' \rho_M(r') \int \frac{\hat{\mathbf{r}}}{|r-r'|} d\Omega$$

$$\int_{r<R} \mathbf{B}(\mathbf{r}) d^3r = -\frac{4\pi}{3} \int \mathbf{r}' l \rho_M(r') d^3r' = -\frac{4\pi}{3} \mathbf{m}_M$$

Nature chooses current

21 cm line in hydrogen, not 42 cm

Historian and Moralist

- Zeroth Theorem of the History of Science
  - "a discovery named after someone often did not originate with that person."
  - Examples:
    - Avogadro said (1811) any gas at STP had the same number of molecules, but that number was determined first by Loschmidt in 1865.
    - Olbers' paradox (1826) was discussed by Kepler in 1610 and Halley and Cheseaux in the 18th century.

Dave's Chance to Champion Some Heros

Ludvig Valentin Lorenz
1867

$$\partial_\mu A^\mu = 0$$
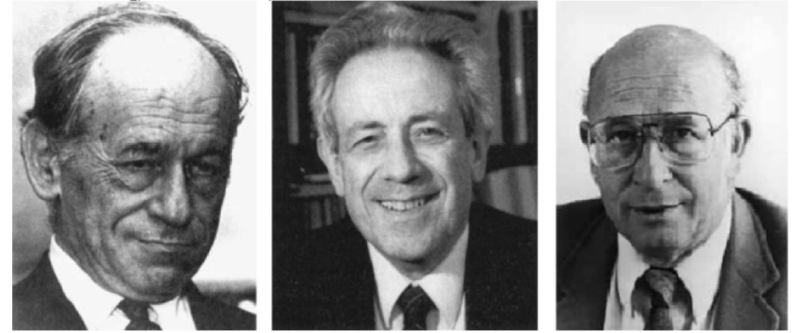
~~Lorentz Gauge~~

Lorenz Gauge

Hendrik Antoon Lorentz
1904

Equation of motion of classical spin in electromagnetic field

L.H. Thomas (1927)

Bargmann, Michel, Telegdi (1957)

$$\frac{dS^\alpha}{d\tau} = \frac{e}{mc}\left[\frac{g}{2}F^{\alpha\beta}S_\beta + \frac{1}{c^2}\left(\frac{g}{2}-1\right)U^\alpha(S_\lambda F^{\lambda\mu}U_\mu)\right]$$

Thomas – BMT Equation

J D Jackson Commemoration

Defying Gravity – 1988

't Hooft does tour de force calculation of gravitational scattering at small angles and high energy.

- – "Two flat regions of space time are glued together at the null plane."

JDJ does it at all energies.

- – "The small angle gravitational scattering of spinless point masses or strings at ultrahigh energies has been discussed recently ['t Hooft; Amati, Ciafaloni, Veneziano] . At small angles,corresponding to large impact parameters,…the scattering cross section becomes the familiar Rutherford form, but with an equivalent interaction four times as large as the relativistic newtonian result...

- – It does not seem to be generally known that these result follow straightforwardly from elemenetary considerations of the small-angle scattering of a test particle by a force center, together with simple Lorentz invariance arguments.."

- – The use of Glauber's approximation for the quantum-mechanical scattering .. Is shown to lead to the exact "Coulomb" scattering amplitude...One thus finds a generally applicable expression ..valid at all energies from newtonian to planckian"

Master of Indignation: Scourge of Editors

- "…the leaky sieve that you call refereeing, languorous and gutless editors, and other relevant matters.''

- "…it was absolutely unconscionable for you to publish his 15 October 1984 response. His last sentence there ("My original conclusion still stands.") is now juxtaposed with ours ("The conclusion of Reiss is not just counterintuitive: It is wrong.").

- "The paper by Nowakowski in the October 1999 issue is the trigger for the release of my pent-up annoyance at the laziness of authors, who when re-inventing the wheel, fail to bother to give credit to the cavemen who preceded them….Who were the referees? .. Would-be contributors have a duty to search out and cite that previous published related work, even if it requires going to the library to find it."

Chastising the Malefactors

- "I protest most vigorously the recent action…another example of the unthinking, inconsiderate, arbitrary LBL bureaucracy at work… The result is deception, pure and simple. …Bob Cahn deserves a <u>written</u> apology from the Laboratory. I trust that you will see that he gets it."

- "Dear Dick, Sid, and Norman,   … You have been very unfair in not giving sufficient prominence to the pioneering work of Baier and Katkov. … A curved path that is an arc of a circle to high accuracy is the same whether produced by a magnetic field or an electric field, and you know it!"

The mountains are calling and I must go.
John Muir

J D Jackson Commemoration